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TICK PARALYSIS *

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Although for many years it has been well known by physicians practicing in southern British Columbia that paralysis may appear in children who have been bitten by ticks, it is only a few months since accounts of such an affection as "tick paralysis" appeared in scientific publications (Todd, 1912, 1912a; Temple, 1912). Medicine owes a debt to these practitioners, Corsan, Henderson, Hall, Kingston, Morris, Rose, Shewan and Temple. Their observations have supplied the first records of paralysis produced in children by the bites of ticks.

The first accounts of the disease were merely short descriptions of the symptoms which had been observed by half a score of physicians in a series of more than twenty-five cases. The patients had been seen during a number of years — Temple saw his first case in 1898 — in various places in southern British Columbia and in the neighboring portions of the United States. All of the patients were children; there were, however, somewhat obscure accounts of instances in which symptoms, resembling those observed in children, had been seen in men who had been bitten by ticks. The history and symptoms were much alike in all of the cases. The usual story was that an active and apparently healthy child suddenly developed a paresis or paralysis of the legs; neither abnormal temperature nor any other symptom but paralysis was constant. After the tick was discovered and removed the symptoms disappeared within a few hours, with the possible exception of a more or less local reaction, often probably due to a secondary bacterial infection, at the site of the tick's bite. In some of the cases reported the tick was not removed; in them the paralysis progressively involved the whole body until reflexes and control of the sphincters were lost, and death ensued.

The symptoms of these cases suggest infantile paralysis (acute poliomyelitis); but they are probably to be distinguished from cases

* I wish to express my indebtedness to all those who have supplied me with the information and material which has made this paper possible; the names of most of them are mentioned in it.

of that disease by the invariably transitory nature of their paralyses. In no instance has "tick paralysis" left permanent disability. It seems impossible to explain these many cases of "tick paralysis" as mere coincidences, in which tick infection has been fortuitously associated with sporadic attacks of a peculiarly mild form of acute poliomyelitis; none of the practitioners who saw these cases have recorded the contemporary existence of definite cases of acute poliomyelitis. Also, the symptoms of these cases of paralysis have little in common with the symptoms of the typhus-like "spotted fever," which is seen in persons bitten by ticks (*Dermacentor venustus*) in some parts of Montana. For these reasons it seems certain that a form of paralysis associated with the bites of ticks occurs in children in western North America and that the infection can be identified with no known disease. Similar cases from Wyoming and Montana have been reported (Bishopp and King, 1913). More recently very similar histories of instances in which paralysis has followed the bites of ticks (probably *Ixodes ricinus* or *I. holocyclus*) have been reported from Australia (Eaton, 1913).

Hadwen (1913) describes the occurrence of paralysis in sheep, which have been bitten by ticks, in British Columbia. He and Nuttall (1914) give references to publications which describe the existence of a paralysis caused by ticks (of a species, *I. pilosus,* other than that which exists in British Columbia) in South African sheep. Hadwen succeeded in producing paralysis in a lamb on which a tick (*D. venustus*) had, experimentally, been allowed to feed. He, with Nuttall (Hadwen and Nuttall, 1913), was successful in producing the same symptoms in a dog. A very complete bibliography of the effects of tick bite can be reached by a search through the papers referred to in this communication. Hadwen, especially, gives a good list of articles on the bites of ticks.

Since the observations contained in the publications mentioned above were published, the cases recorded below have been reported.

Dr. W. J. Knox, Kelowna, B. C., records two cases.

April 23, 1913, a boy of 4 years had pronounced flaccid paralysis from the hips down. He could not stand; his arms were weak; there was hyperesthesia; the pupils were normal; the temperature was 100 F.; the pulse was 112. The first symptom had been a little stiffness of the legs twenty-four hours previously; it progressed until in twelve hours walking was extremely difficult. A tick was found in the left axilla. It was removed by snipping it out with the tissue about its head; the wound was dressed antiseptically. A purgative was given to the child and, under slight stimulation, the pulse quickly became full and steady. In twenty-four hours the child could move his limbs fairly well, and in forty-eight hours he was apparently as well as ever.

April 21, 1914, a girl of 3 years had slight paralysis of the right leg. The temperature was normal. Her condition was said to be better than it had been two hours previously; so rest and a purgative were prescribed. Twelve hours later the child was stuporous. Her legs and arms were entirely par-

alyzed; she could neither articulate nor swallow, and seemed to be sinking very rapidly. The pulse was 130, small and weak. The temperature was 102 F. No tick was found on the child's body, but the hair was clipped short and a small wood tick was found at the base of the skull. It was removed by snipping it out with the tissue surrounding its head. The wound was dressed antiseptically and purgatives and stimulants were given; in six hours the child's temperature was 99.4 F., her pulse 100 and regular and she was conscious and asking for water. In twelve hours she could move her limbs and in five days was running about as well as ever.

Dr. Knox also reports a case of quite another type in an adult.

April 27, 1914, a man of 28 years was seen. He gave a history of having pulled off the body of a tick, leaving the head behind, from the calf of his left leg. At the site of the bite was a large bluish-black area surrounded by much induration. The patient's body was covered with a spotted erythema. He felt very ill, and complained of vertigo and of pains in the back and in the legs. His pulse was 108, his temperature 102.5 F. Sensation was lost in the right leg from 6 inches below the hip-joint; the left leg was paralyzed. The head of the tick was excised and the wound dressed antiseptically. A purgative was given and in twelve hours the temperature had dropped to 99.6 F. and the pulse to 86. In thirty hours the temperature was normal, and the rash and pain were gone; in four days the patient, being well, was discharged.

Dr. Knox records an instance in which a very thin colt, so weak that it could not stand, was covered with ticks; the ticks were removed and within a few days the colt was able to walk and gradually regained its health. (It is possible that this was nothing more than a case of severe "tick worry.")

Dr. Elmer Fessler, St. Regis, Montana, records two cases.

On the morning of May 19, 1914, a 2-year-old girl was found to be unable to walk or stand, although she had slept well and had been quite well on the previous day. She tried to walk several times during the day but she was unable to do so. When the physician first saw her, on the morning of the twentieth, her temperature was 96.5 F., her pulse 120 and her respiration was normal. She could move her legs, but she could not stand, and the leg reflexes were gone. There was considerable loss of function of the arms. The mother said more than on the previous day. No urine had been passed for twenty-four hours. Although the child was somewhat peevish, she took her food as usual. Two ticks (*Dermacentor venustus*) were removed from the nape of the neck; one was a half-engorged female, the other a male. The child was given cathartics. In six hours her hands were moved less clumsily and a little later she tried, unsuccessfully, to stand. At 9 the next morning she could walk and by noon was running about as usual. She has been quite well ever since.

In 1905 a girl of 5 years was seen who was said to have been unable to walk for forty-eight hours. She could not move her legs which were without reflexes. She could move her arms clumsily, but could hold nothing in her hands. A large tick was removed from the base of the skull and on the following day she seemed to be quite well, save for a slight weakness that persisted for some days.

Dr. A. W. Kenning, who practiced in Rossland, southern British Columbia, for sixteen years, mentions two cases.

One, the only fatal case, which he saw, was in a girl of 8. She had general paralysis and when the tick was found on her arm, she was comatose with a rapid pulse and high temperature. The other case was a child of 6 who had general paralysis; the whole body was involved. On removing the tick from the child's head, she recovered as was usual in such cases.

Dr. G. S. Gordon, Vancouver, B. C., has records of one case.

In 1904 (?) a girl of 5 years was seen. The child came of neurotic stock; she seemed well in every particular save that, though she could move her arms and legs while sitting on the floor, she could not walk nor put one leg before the other when she was supported in the erect position. A second practitioner, whose opinion was asked, told the parents to look for "wood ticks." One was found and on its removal the symptoms disappeared.

Dr. R. W. Irving, Kamloops, B. C., records a case in a child.

May 1, 1912, a boy of 8 years was seen. He complained of numbness in his legs and was unable to stand. He seemed rather sleepy and dull; but otherwise was healthy, save that he could only move his legs in an ataxic manner while lying in bed and that at times his arms seemed to become weak. The special senses were not affected nor were the cranial nerves involved. The knee-jerks were not obtainable. There was no ankle clonus, nor Babinski's sign. The sphincters were under control and there were no areas of anesthesia or hyperesthesia. The pulse was normal and the temperature was 99.2 F. A tick was found at the base of the skull and it was removed. Under rest and catharsis the boy, in three or four days, became perfectly well.

Dr. Irving, with Dr. Murphy, saw a case in which definite nervous symptoms in an adult were associated with the presence of a tick.

A normal, well-nourished male of 40 years complained that four days previously he found it difficult to speak and that he was awkward in his movements. He had been perfectly well and said that he had felt as though he were "partially drunk." A day later he fell on attempting to arise in the morning and was unable to balance himself in any way. When the patient was seen there were few constitutional symptoms and his only other complaint was that he felt "a bit seedy." On examination his hands and arms were found to be weak and incoordination was definitely present. The knee-jerks were absent; there was no ankle clonus, Babinski's sign, area of anesthesia or hyperesthesia, and no involvement of cranial nerves nor loss of sphincter control. A tick was found on the upper part of the back and removed. The symptoms commenced to disappear within twenty hours. In three days the man was as well as ever, and in three days more he was married.

These and other cases add a little to the first descriptions of the affection; they show that an elevated temperature, a rapid pulse and respiration and other constitutional conditions may frequently be symptoms. It also seems probable that nervous symptoms may supervene in adults who have been bitten by ticks. Convulsions, sudden stupidity and clumsiness are mentioned as symptoms that may follow tick bite. One physician asserts that in southern British Columbia practitioners, who have been in the country for long, always look for ticks on a child who has a convulsion. One or two physicians mention cases which suggest that spotted fever may not be entirely confined to Montana. There are many records of ulcers and other inflammatory lesions at the site of ticks' bites. Sometimes these lesions are said to be suggestively obstinate to ordinary treatment.

The experiments recorded below were made in the hope of producing, under experimental conditions, paralysis in laboratory animals, by the bites of ticks.

The way in which the experiments were done was practically identical in each instance. The animals, together with control animals, were well cared for. The lambs, when the experiments commenced, were from 4 to 6 weeks old; they were kept in pens with their mothers. The puppies were about the same age; they were kept in individual cages and fed on milk. The ticks were attached either to the nape of the neck or to the loins as is stated. The hair was removed either by slipping and shaving or by epilating powder. The ticks were then placed on the skin beneath a finely perforated porcelain filter cone, which measured about 1 inch in diameter at the base and 1 inch in height. The cone was fastened to the animal by an ample bandage of adhesive plaster, firmly stitched in position. As a rule, this method of attaching the ticks was satisfactory. In only one or two instances did the ticks find their way beneath the edge of the cone and become lost or fixed to the plaster. Paralysis was produced in no experiment.

Monkey 1.—Aug. 16, 1912. Two ticks (*D. venustus* or *D. andersoni*), sent by Dr. J. B. McClintic, Victor, Mont., were placed on the nape of the neck of a large rhesus monkey; August 21, both ticks, each half engorged and firmly attached, were removed. August 24, three ticks, from the same source, were placed on the nape of the neck; August 31, two engorged ticks were removed; one tick had disappeared. November 18, four ticks, obtained by Dr. Lee Ganson of Odessa, Wash., from "jack rabbits," were placed on the nape of the neck of this monkey; November 30, during the night the monkey pulled off the bandage and destroyed the ticks.

Monkey 2.—Aug. 16, 1912, three ticks (*D. venustus* or *D. andersoni*), sent by Dr. J. B. McClintic, Victor, Mont., were placed on the nape of the neck of a small rhesus monkey; August 20, the half-engorged ticks were removed. August 24, two ticks, from the same source, were placed on the neck; August 30, one engorged tick was removed; the second was dead.

Monkey 3.—May 2, 1913, three ticks (not identified) were placed on the nape of the neck of a large rhesus monkey. One of these ticks was that which was removed from the little boy whose case is recorded above by Dr. Knox at Kelowna, B. C. The other two were sent by Dr. Boyce, from a horse, from the same place. May 26, the engorged ticks were removed.

Ten ticks, all of them very probably *D. venustus,* fed on one or the other of these three monkeys. Paralysis appeared in none of the three, although the child from which one of the ticks had been taken was paralyzed.

Lamb 1.—April 20, 1914, two ticks (*D. venustus*) from H. P. Wood, Esq., Florence, Mont., were placed on the neck of a lamb about 3 weeks old. The ticks were collected from cattle in a district where "spotted fever" exists. April 21, the lamb was obviously disinclined to move. April 22, the lamb died. A naked-eye examination at the autopsy revealed nothing beyond four or five superficial, almost petechial, pneumonic areas on the lungs. One of these was sectioned and the lung was found to be congested and collapsed, rather than pneumonic. The stomach and intestines were filled with normally digested food.

Lamb 2.—On April 20, 1914, three female ticks, two *D. venustus* and one *D albipictus,* collected by Seymour Hawden, D.V.Sci., from horses at Keremeos,

B. C., were placed on the neck of a lamb about 4 weeks old. April 30, the three ticks, none of them engorged, were removed. Four ticks, three male and one female *D. venustus*, sent by H. P. Wood, Esq. (see Lamb 1), were placed on the neck; May 9, the engorged female and three unfed male ticks were removed. May 28, an engorged female *D. venustus*, taken by Dr. Arthur from the skin of a bear, at Nelson, B. C., was placed on the neck; June 5, the tick was removed unfed. June 19 two ticks, *D. venustus*, sent by R. A. Cooley, Esq., Bozeman, Mont., were placed on the neck; June 24, both ticks were removed, unfed.

Lamb 3.—April 24, 1914, four ticks, from H. P. Wood, Esq., Florence, Mont., were placed on the neck; April 30, two of the ticks were lost and one dead, the remaining living tick was not engorged. Four other ticks, two male and two female *D. venustus*, from the same source, were placed on the lamb; May 9, one of the ticks was dead, the three living ones were removed, none were engorged. May 28, one female, *D. venustus*, partially engorged, from Dr. Arthur (see above) was placed on the neck; June 5, the tick was dead; and probably was never attached. June 19, two *D. venustus*, from Bozeman, Mont., were placed on the neck; June 24, one unfed tick was removed, one was missing. June 25, three *D. venustus*, two females and one male, from Bozeman, Mont., were placed on the neck; July 2, one engorged female and one attached male tick was removed.

Lamb 4.—April 24, 1914, one male and one female *D. venustus*, from Florence, Mont., were placed on the neck; April 30, ticks removed; both had attached; one was fully engorged. Four other ticks, one male and three females, from the above source, were placed on the loins; May 9, ticks removed; all had attached; three were engorged. May 28, three partially fed ticks, one male and two female *D. venustus*, from Dr. Arthur (see above) were placed on the neck; June 5, ticks removed; the two female ticks were engorged; the male was not. June 6, a half-engorged female *D. venustus* was placed on the neck. This tick was one of those removed from the case recorded above by Dr. Fessler. June 12, tick removed; probably had not attached. June 19, a male *D. venustus*, also from Dr. Fessler's case, previously fed on Puppy 1, was placed on the neck; June 24, tick dead. June 25, a male and a female *D. venustus* from Bozeman, Mont., were placed on neck; July 2, the engorged female and unfed male ticks were removed.

Lamb 5.—April 30, 1914, a tick (unidentified) from the case described above by Dr. Irving, was placed on the neck; May 9, tick dead; apparently had not attached. May 28, one male and two female *D. venustus* from Dr. Arthur (see above) were placed on the neck; June 5, ticks removed; two were engorged; one not. June 19, two ticks, *D. venustus*, from Bozeman, Mont., were placed on the neck; June 24, ticks removed, only one was half engorged. June 25, four ticks, two male and two female *D. venustus*, from Bozeman, Mont., were placed on the neck; July 2, one female was dead, the remainder being attached, were left in position; July 7, an engorged female and one dead and one still attached male were removed.

Lamb 6.—May 5, 1914, two female *D. venustus*, from Dr. Hawden (see above), were placed on the neck of this lamb; May 16, both ticks, attached but not engorged, were dead. May 28, one partially engorged female *D. venustus* from Dr. Arthur (see above), was placed on the neck; June 5, tick dead, probably had not attached. June 19, one male and one female *D. venustus*, from Bozeman, Mont., were placed on the neck; June 24, both ticks dead; one attached; neither engorged. June 25, one female and one male *D. venustus*, from Bozeman, Mont., were placed on the neck; July 2, male dead, female engorged.

Lamb 7.—May 9, 1914, a female *D. venustus*, obtained from surveyors by Dr. Arthur of Nelson, B. C., was placed on the neck of this lamb. May 16, tick removed, three-fourths engorged. May 28, two partially engorged female *D. venustus*, obtained from Dr. Arthur, at Nelson, B. C., from a bear skin, were

placed on the neck; June 5, both ticks dead, probably never attached. June 19, two ticks, *D. venustus*, from Bozeman, Mont., placed on the neck; June 24, ticks removed, both attached, one half engorged. June 25, two ticks, *D. venustus*, from Bozeman, Mont., were placed on the neck; July 2, one male tick and one attached female removed, both were unfed.

About twenty ticks, almost all of them adult male or female *D. venustus,* fed on one or the other of seven lambs. Six of the lambs remained in perfect health. One of them (Lamb 1) died on the second day after two ticks were placed on it; it is not probable that the ticks were the cause of death, since other ticks from the same source were harmless to similar animals.

Guinea-Pig 1.—May 6, 1914, a male and a female *D. venustus* sent by H. P. Wood, Esq., Florence, Mont., were placed on the loins; May 16, ticks removed, the female was partially engorged. June 3, dead; the guinea-pig had seemed to be quite well, and temperature was not abnormal until May 16, when daily observations were discontinued. At autopsy, there were no signs of irritation about tick bites; the cause of death was bronchopneumonia.

No sign of paralysis followed the feeding of a single tick on a guinea-pig.

Puppy 1.—June 6, 1914, a male *D. venustus*, sent by R. A. Cooley, Esq., Bozeman, Mont., was placed on the back of a puppy, about 6 weeks old. This tick was one of those taken by Dr. Fessler from the case recorded above by him; June 12, tick removed, unattached and unfed. June 19, two male *D. venustus*, from Bozeman, Mont., were placed on the back; June 24, two ticks removed, both unfed and dead. June 25, one male and one female *D. venustus*, from Bozeman, Mont., were placed on the loins; July 2, both ticks dead, neither fed.

Puppy 2.—June 19, 1914, two male *D. venustus*, from Bozeman, Mont., were placed on the loins of a puppy about 8 weeks old; June 24, both ticks removed, unfed and dead.

Puppy 3.—June 19, 1914, two female *D. venustus,* from Bozeman, Mont., were placed on the loins of a puppy about 8 weeks old; June 24, ticks removed, both engorged.

Paralysis did not appear in a puppy on which two ticks fed.

The ticks used in all of these experiments were identified with the assistance of the key published by Banks (1908). *Dermacentor venustus* and *D. albipictus* were the only ticks received from southern British Columbia, and of these the former was much the more common. In a personal letter, Hadwen wrote that it is difficult to get *D. venustus* to feed under laboratory conditions unless it has been recently collected; the diaries of the above experiments ratify his statement. The ticks used in these experiments were confined in Ehrlenmeyer flasks plugged with cotton wool, and were kept in a humid atmosphere at 25 C. Care was taken to give every tick every chance for feeding; several of the ticks used in these experiments had opportunities for feeding on two or more animals. These conditions seemed to agree with some females which laid many fertile eggs; but about half of the females laid only a few eggs and these infertile ones.

In the records of the tick-feeding experiments only those ticks which were definitely engorged are counted as having fed. It is unfortunate that their number is not larger and, especially, that the ticks which had been removed from paralyzed children would not all feed well on the experimental animals. Enough fed, however, to justify the statement that, under the conditions of these experiments, not every bite of a tick (*D. venustus* and *D. albipictus*) is able to cause paralysis in the laboratory animals employed.

It was thought that the paralysis produced by the bites of ticks in children might be caused by some toxin secreted by the ticks. Experiments were therefore designed to ascertain whether an extract capable of producing paralysis in laboratory animals could be obtained from the bodies of ticks.

Experiment 380.—About 4 c.cm. of larvae of "Texas fever ticks," (*Margaropus* sp.?), obtained from Washington, D. C., through the courtesy of the Bureau of Animal Industry, were dried for six weeks, and were then ground up in 50 c.cm. of a 4 per cent. solution of glycerin in distilled water. The resulting mixture was shaken for one and a half hours and then passed through a Buchner and a Berkefeld filter. The fluid so obtained was inoculated beneath the skin of the rump of two rats and two mice; one rat and one mouse received 2 c.cm., the other rat and mouse 1 c.cm. The two mice died within twenty-four hours; no cause of death was evident. The rat which received 1 c.cm. died ninety-six hours after inoculation; the cause of death was not evident. The second rat died two weeks after inoculation, from bronchopneumonia; neither it nor any of the animals had ever shown any sign of paralysis, or of suppuration at the site of inoculation.

Experiment 400.—Ten adult *Margaropus annulatus* and about 700 larvae, also obtained from Washington, D. C., were dried, ground up in glycerin and water, shaken and filtered in the same way as was done in Experiment 380. Four c.cm. of the filtrate was inoculated beneath the skin at the back of the neck, of two rats; one received 2 c.cm., the other 4 c.cm. Neither rat developed any sign of paralysis nor was there suppuration at the site of inoculation in either.

Experiment 531.—About 3.5 c.cm. of dried ticks of all ages and of both sexes were employed. Most of them were adults. With the exception of one or two *D. albipictus*, all were *D. venustus*. These ticks were those, or their progeny, which had been used in the feeding experiments described above. All were ground up in 50 c.cm. of a 4 per cent. solution of glycerin in distilled water, shaken for two and a half hours and then filtered through a Buchner and a Berkefeld filter. Respectively, 2 c.cm., 4 c.cm. and 5 c.cm. of the clear filtrate was inoculated under the skin of the rumps of three young white rats, weighing about 30 gm. each. Paralysis appeared in none of them, although as in the previous experiments, all showed some disinclination to move; probably because of the soreness at the site of inoculation. One rat died four days after the inoculation. There was no sign of suppuration at the wound, and the cause of death was not evident to naked-eye examination, at the autopsy.

Experiment 532.—Five male, eight female and about 1,500 larval ticks, all living *D. venustus*, which had been used, or were the progeny of those used, in the above feeding experiments, were ground up, shaken and filtered in the same way as in Experiment 531. Respectively, 2 c.cm., 4.5 c.cm. and 6 c.cm. of the clear filtrate obtained was inoculated beneath the skin over the rump

of three young rats, each weighing about 30 gm. All of the rats survived; in none did paralysis appear.

EXPERIMENTS 550-551.—Three boxes, each containing a female *D. venustus*, and young seed ticks from her, were obtained from the Bitter Root Valley through the courtesy of R. A. Cooley, Esq. In two of the boxes the females and many hundreds of seed ticks were dead; in the third box the female and seed ticks were living. All were ground up together in 50 c.cm. of normal saline solution, shaken for two hours and then passed through Buchner and Berkefeld filters. About two-thirds of the whole filtrate obtained was inoculated subcutaneously over the withers of a 4½-months old lamb; 3.5 c.cm. of the filtrate was inoculated subcutaneously over the rump of a young white rat. Paralysis was never observed in either of these animals.

It has been proved (Nuttall and Strickland, 1908) that ticks secrete an anticoagulin which prevents blood from clotting. Observations were, therefore, made to ascertain whether an anticoagulin existed in the filtrate of extracted ticks, which was inoculated into the animals used in Experiments 380, 400, 531 and 532. Blood from a healthy man was drawn up into capillary tubes, of about 1 mm. internal diameter, with one-third, occasionally one-fourth, of its volume of the filtrate to be tested. A control tube was made in every instance, in which a 4 per cent. solution of glycerin was substituted for the filtrate. The tubes were then kept at room temperature, and the time in which the blood of each coagulated was observed. The tick extract used in Experiments 380 and 400 seemed to have no definite power of preventing coagulation, since coagulation usually occurred in both tubes in the same length of time. The tick extracts used in Experiments 532 and 531 had a definite, though slight, power of preventing coagulation. That used in Experiment 532 was definitely more powerful than that used in Experiment 531; with it, coagulation had usually only commenced at the end of three minutes, while it was complete at the end of that time in the control tubes. It is possible that the lack of symptoms obtained by the inoculation of the filtrates, as well as the lack of coagulating power of the filtrates used in Experiments 380, 400 and 531, may be explained in part by the comparatively large quantity of diluent in which the ticks were extracted. It must also be remembered that only in Experiment 532 was the extract made from living ticks.

It can be concluded that an extract of ticks, prepared in the manner described, will not cause paralysis in rats even when it possesses slight power to prevent the coagulation of human blood.

SUMMARY

1. Previous publications have proved:

(*a*) That a paralysis in children may be associated with the bites of ticks in western North America and in Australia.

(*b*) That a paralysis of sheep has been associated with the bites of ticks in British Columbia and in South Africa.

(*c*) That the ticks associated with these affections are of more than one sort.

(*d*) That *Dermacentor venustus* has produced paralysis in lambs and in a puppy in experiments made under laboratory conditions.

(*e*) That the paralysis following tick-bite is probably an individual and novel condition.

2. The paralysis of children is not infrequently accompanied by elevation of temperature and by other constitutional symptoms; it is possible that symptoms resembling those observed in children sometimes may appear in adults who have been bitten by ticks.

3. Under experimental conditions by no means every tick bite produces paralysis in laboratory animals.

4. A weak extract of ticks will not cause paralysis when injected into white rats, even though it possesses definite power to prevent the coagulation of blood.

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LARVAL TREMATODES FROM NORTH AMERICAN FRESH-WATER SNAILS

PRELIMINARY REPORT *

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Almost nothing is known of the life histories of the trematodes of North America. Some progress has been made in the study of the adults, but as yet there are only a few scattered observations on larval stages. During the fall of 1913 the study of the larval trematodes from fresh-water snails was undertaken by the writer at the suggestion of Prof. Henry B. Ward, as an attempt to open up this undeveloped field. The snails studied, which were obtained from several sources, yielded a surprisingly large number of species of cercariae, belonging to a wide variety of trematode groups. Fourteen new cercariae with their sporocysts or rediae were studied in detail, especial attention being given to observations on the living animals. The complete results of this work, embodying a detailed discussion of anatomy, histology and relationships, will appear shortly. The present report contains some of the more interesting observations on the structure and activity of these forms.

In the grouping of the cercariae the classification of Lühe (1909: 173-210) has been followed in most instances. In those groups in which the structure of the cercaria corresponds fairly closely to that of the adult, as in the amphistomes and the echinostomes, this classification is very satisfactory, but in those divisions where larval adaptations dominate the structure and where little is known of further development, as, for example, in the Stylet cercariae or microcercous group, the arrangement is certainly to some extent purely artificial.

Of the fourteen cercariae studied, one is a monostome, two are amphistomes and the rest belong to five different subdivisions of the distomes.

MONOSTOME CERCARIAE

Rediae and cercariae of a monostome, which I propose to name *Cercaria urbanensis,* were found during December 1913, in the livers of 5 per cent. of the full-grown specimens of *Physa gyrina* Say, from a drainage ditch near Urbana, Ill. There were present in the infected livers immature and fully developed rediae and free cercariae in dif-

* Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 35.

ferent stages of development. No rediae were present in which other rediae were developing and no mature cercariae remained in the rediae.

When freed from the liver of the snail the redia of this species has considerable power of extension and contraction, the immature ones especially stretching out the anterior end and reaching in all directions. No locomotor appendages were present in any stage and no locomotion was noted. In shape they are elongate sacs, smallest at the anterior end and widest in front of the posterior extremity. The intestine is voluminous, having a diameter of from one-third to two-thirds the width of the body and reaching almost to the posterior extremity.

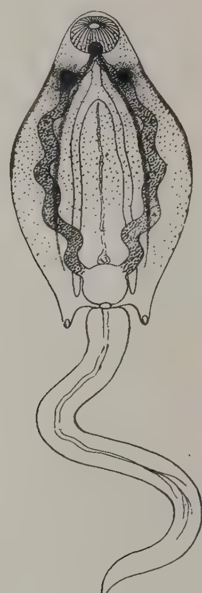

Fig. 1.—Mature *Cercaria urbanensis,* ventral view. Cystogenous glands not shown. X 140.

The methods of locomotion of *Cercaria urbanensis* (Fig. 1), either when swimming in open water or when creeping on a substratum, are very striking. The body when swimming is contracted into a round ball and the powerful tail is curled ventrad and lashes with great rapidity driving the animal with considerable speed through the water. In spite of the absence of a ventral sucker, the cercaria is able to creep by utilizing two projections which form the posterior lateral angles of the body. These projections, which are reinforced by cuticular struc-

tures, are thrust against the surface in a manner analogous to setae and aided by the oral sucker push the animal along. *Cercaria urbanensis* encysts in the open and the complete process of encystment was followed under the microscope.

The shape of *Cercaria urbanensis* is quite variable. An individual may contract until its length is 0.27 mm. and its width 0.20 mm., and it may extend itself to 0.54 mm. in length and 0.11 mm. in width. The tail changes its length from 0.20 mm. to 1.2 mm. The histological structure of this tail is very interesting on account of its adaptation for powerful movement. The structure of this cercaria agrees in a general way with that of a group of closely related monostomes of which *Cercaria imbricata* Looss (Looss, 1896: 192-197), and *Cercaria ephemera* Nitzch (Ssinitzin, 1905, Plate 4, Figs. 75 and 76), are examples. It differs from these forms in details of structure, such as the length of the intestine of the redia and the structure of the locomotor projections of the cercaria. *Cercaria hyalocauda* Haldeman, a monostome cercaria from North America, as described by Evarts (1880) is considerably larger than *Cercaria urbanensis*.

AMPHISTOME CERCARIAE

Amphistome cercariae are very easily recognized by the presence of the large acetabulum at the posterior end of the body. Although large numbers of adults of this type have been reported, but three cercariae are found in the literature, namely, the cercaria of *Diplodiscus subclavatus* (Goeze), best described by Looss (1892: 162-166); *Cercaria pigmentata* Sonsino, which was shown by Looss (1896: 185-191) to be the larval form of *Paramphistomum cervi* (Zeder), and the cercaria described by Looss (1896: 177-185) as the larval form of *Gastrodiscus aegyptiacus*. Of these cercariae that of *Paramphistomum cervi* belongs to the subfamily *Paramphistominae,* and the other two to the *Diplodiscinae*. My studies add to the second subfamily two cercariae, which differ from the known forms in details of structure both of the redia and cercaria.

These two cercariae were collected from specimens of *Planorbis trivolvis* Say, from three localities. Two snails out of eighteen of this species from Lawrence, Kan., and one from large numbers examined from around Urbana, Ill., contained the first of these forms, a large pigmented cercaria, to which the name *Cercaria inhabilis* is given. The second, a small unpigmented cercaria, *Cercaria diastropha,* was found in one of twenty specimens of *Planorbis trivolvis* from a small pond in the suburbs of Chicago. In all the infected snails adult and immature cercariae were found free in the livers, the mature forms being nearest the periphery, and the active rediae contained no fully developed cer-

cariae. There were no sporocysts present and no rediae in which rediae were developing.

The rediae of *Cercaria inhabilis* were all in about the same stage of development. When freed from the snail they were very mobile, extending and contracting and making some progress even on the smooth surface of a watch glass. There are present two pairs of locomotor appendages and the posterior extremity is attenuated and pointed. The pharynx is small in proportion to the size of the body and the intestine is voluminous and extends more than one-third of the distance from the anterior to the posterior ends.

Cercaria inhabilis (Fig. 2) swims sluggishly in open water. It contracts its body and lashes rapidly with its tail moving forward in an unwieldy irregular fashion. In fact, the body is too large in proportion to the size of the tail for rapid locomotion. On a substratum the cercaria extends and contracts its body, but is unable to creep with the aid of the suckers. It is the largest of the cercariae studied. In the different stages present the development of the pigmentation could be traced from little spots around the eyes until it spread through most of the body. Although cystogenous glands are highly developed, filling most of the body, none of the cercariae under observation were seen to encyst.

Cercaria diastropha (Fig. 3) resembles *Cercaria inhabilis* in general structure. It differs from this form in the size and shape of the body, the ratio in the size of the suckers and in the position of the acetabulum, in the amount of pigmentation, and in the anlage of the reproductive organs.

The redia of *Cercaria diastropha* is even more active than that of the former species, being able to move well with the aid of the two pairs of locomotor appendages and to stretch to five or six times its usual length. This mobility is correlated with extreme development of the circular muscles, which show clearly externally as annular rings.

The only adult trematode from North America which resembles these amphistome cercariae in structure is *Diplodiscus temporatus* Stafford. Cary (1909) described as belonging to the life history of this species sporocysts and rediae, both containing cercariae from *Goniobasis virginica* obtained near Princeton, N. J. In 1911 Cary kindly sent me some of the material used in the preparation of this paper, including specimens of *Diplodiscus temporatus* from his experimental tadpoles. A study of this material and a careful analysis of Cary's account shows that he has described as belonging to this species two entirely different types of cercariae, that is, a large gymnocephalous cercaria developing in rediae and a small xiphidiocercaria developing in sporocysts. Since in his infection experiments he used only the

larger species, he certainly can have no evidence that the smaller form has any connection with *Diplodiscus temporatus*. Therefore, Cary's whole discussion in the embryological part of the paper (1909:617-647) which is based on the study of the sporocysts and the cercariae developing in them, cannot without further evidence be given a place

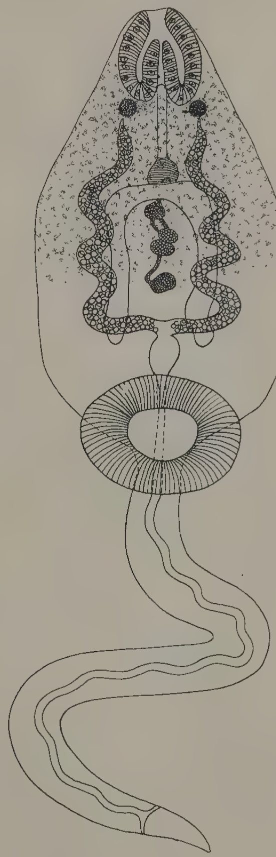

Fig. 2.—Mature *Cercaria inhabilis,* ventral view. Cystogenous glands not shown. X 88.

in the life history of *Diplodiscus temporatus*. However, it proves the thesis which Cary sets out to make that the embryo in the sporocyst develops from parthenogenetic eggs, and is therefore a very important contribution to trematode embryology. I am convinced that the larger form, which I shall call *Cercaria megalura,* is not the cercaria of

Diplodiscus temporatus, as Cary maintains, because it is so fundamentally different in structure from all known amphistome cercariae and from the adult of this species. Further, Cary's infection experiments are not sufficiently controlled to be conclusive and admit of an entirely different interpretation from the one he gives. To produce infection he puts the tadpoles into jars with snails which contain these cercariae and because the tadpoles were later found to be infected with

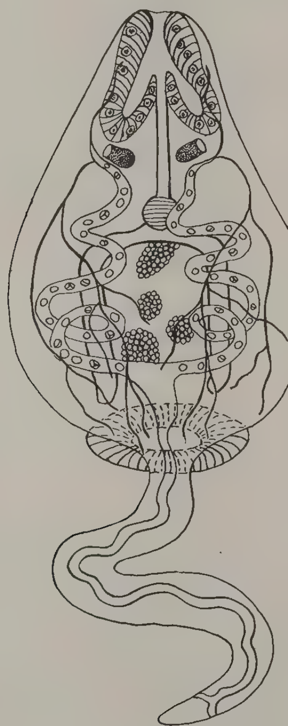

Fig. 3.—Mature *Cercaria diastropha,* ventral view. Cystogenous glands not shown. X 176.

Diplodiscus temporatus, he concluded that these trematodes had developed from cercariae in the snails. The first adults were found one week after the beginning of the experiments. These cercariae are so fundamentally different from the adults into which Cary supposed that they developed in one week's time, that I am convinced that he is in error in his conclusions and that the experimental tadpoles, in spite of

the checks which he used, were already infected with *Diplodiscus temporatus*. Lack of space admits in this report of only the bare outlines of the conclusions in this matter. A full discussion of the data and arguments which have led to the above conclusions will be published in the final paper.

The smaller of Cary's two species of cercariae I shall call *Cercaria caryi* (Fig. 4). Since it is very small and no living material is available for study, no extended description will be attempted. It evidently belongs to Lühe's group of Cercariae microcotylae under the Xiphidiocercariae. I was fortunate enough to obtain further material of *Cercaria megalura,* so that a detailed study was possible. Some facts concerning this form and certain corrections of Cary's description will be given here.

DISTOME CERCARIAE

The great bulk of known cercariae belong in this division. In my material were eleven distome cercariae representing five of the subgroups.

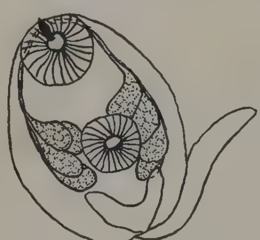

Fig. 4.—Mature *Cercaria caryi,* ventral view. From Cary's material. X 280.

Gymnocephalous Cercariae

Since beyond the fact that they develop in rediae the cercariae placed in this subdivision agree only in the absence of certain characters, it is probably an unnatural group. However, in the present state of our knowledge it is very convenient to retain it. From my material only *Cercaria megaluria,* wrongly described by Cary as the larva of *Diplodiscus temporatus,* belong here.

Rediae containing cercariae of this species were found in one from seventy-three specimens of *Pleurocera elevatum* Say, from the Sangamon River near Mahomet, Ill. This species, as Cary entirely failed to note, resembles very closely in both activity and structure *Cercaria distomatosa* Sonsino, best described by Looss (1896: 197-204). These two species differ in the size and the relations of the digestive system of the redia and in the size of the cercaria and in the relations of its excretory system. Since they differ very greatly from all others of the

gymnocephalous group, I propose to make them the basis of a subgroup, to which the name Megalurous cercariae may be given.

The rediae of *Cercaria megalura* are very active and the region back of the locomotor appendages on account of its mobility and attenuation resembles a tail. The anterior region of the body can be extended and contracted freely and with the aid of the locomotor appendages locomotion was possible. The intestine is very voluminous, being from one-third to two-thirds the diameter of the body and reaching almost to the posterior tip.

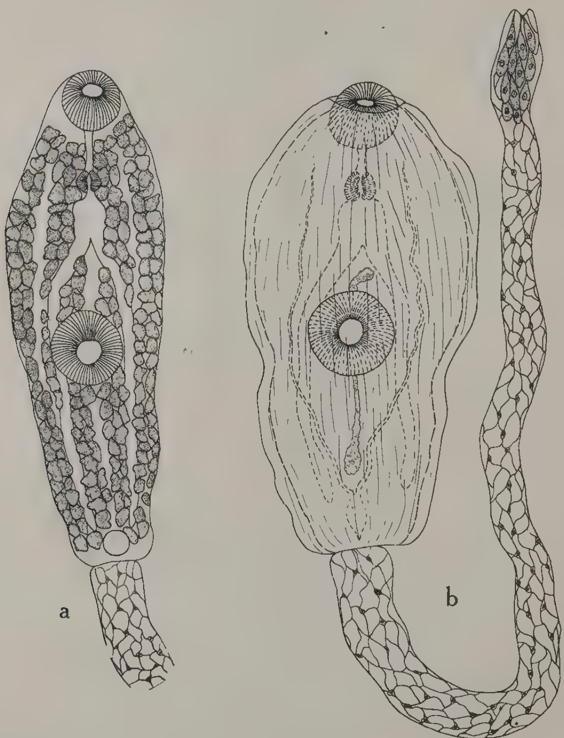

Fig. 5.—Mature *Cercaria megalura,* ventral view. (*a*) Before extrusion of cystogenous material. X 195. (*b*) After extrusion of cystogenous material. X 195.

Cercaria megalura (Fig. 5a) is unable to use its tail for swimming in open water, but on a surface creeps fairly rapidly with the aid of the suckers. At times the cercaria becomes attached by the tip of its tail which is furnished with an adhesive organ. It then becomes

extended to five or six times its usual length and is greatly attenuated. In this position it moves continually with a wriggling serpentine motion, which makes it resemble a tubificid worm. This activity probably aids in transfer to a secondary intermediate host. None of the cercariae were seen to encyst, although large numbers of them extruded cystogenous material in the form of a sort of open tube around the body (Fig. 5b).

The study of both Cary's and my own material of *Cercaria megalura* shows that he is in error in his description of the digestive system, the tail, and the anlage of the reproductive organs as is evident on comparison of Cary's Figure 6 of Plate 30 with Figures 5a and 5b of this paper.

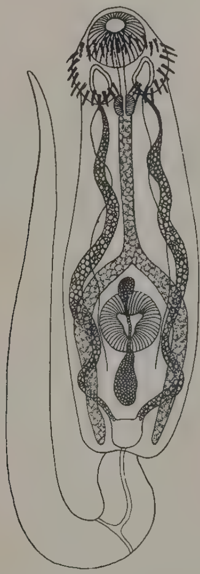

Fig. 6.—Mature *Cercaria trivolvis,* ventral view, cystogenous glands not shown. X 195.

Echinostome Cercariae

Cercariae belonging to the family Echinostomidae are very easily recognizable because of the presence as in the adult of the anterior collar and crown of spines. The structure of the excretory and digestive systems are also very characteristic for the whole group. The anterior crown of spines gives a very definite basis for comparison between larvae and adults, and many suggestions of life histories have been made on this character.

Two cercariae of this group were found in the material studied. In neither of them are the anterior spines like any of the known American adult echinostomes, and they differ in a number of points from any of the cercariae of this group described.

Rediae in which cercariae were developing, as well as encysted cercariae of the first of these species, for which the name *Cercaria trivolvis* is proposed, were found in several specimens of *Planorbis trivolvis* from Urbana, Ill. *Planorbis trivolvis* is able, then, to serve both as intermediate and secondary intermediate host for this trematode. The second echinostome species, *Cercaria rubra,* was found encysted in six out of thirty-six specimens of *Campeloma subsolidum* Anthony, from Hartford, Conn. The snail in this case is merely the secondary intermediate host.

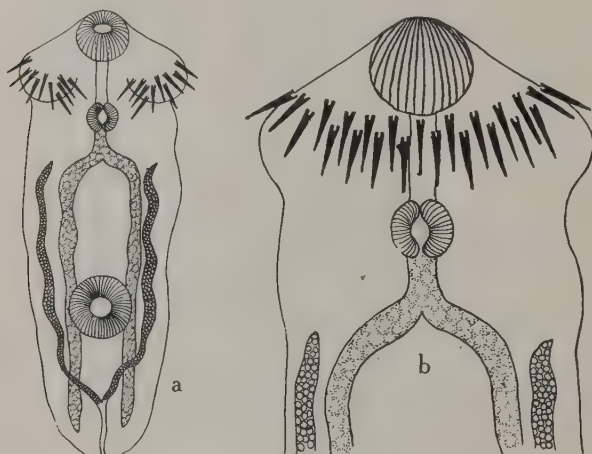

Fig. 7.—*Cercaria rubra.* (*a*) Freed from cyst, ventral view. X 195. (*b*) Anterior end of cercaria, dorsal view. X 390.

The rediae of *Cercaria trivolvis* are much like those described for other echinostomes, differing from them only in details of structure.

The cercaria (Fig. 6) of this species moves actively, both by swimming in open water and by creeping on a surface. The tail is powerful and extends when the animal is swimming to two or three times the length of the body. For the swimming movement the cercaria bends ventrad almost double, with the posterior half of the body above the anterior. The tail, which extends out beyond the anterior end, lashes vigorously and propels the animal rapidly. Of all the cercariae

observed only *Cercaria urbanensis* moved more rapidly than *Cercaria trivolvis.*

The crown of spines of *Cercaria trivolvis* consists of thirty-seven spines of equal size, arranged in two alternate rows which are broken in the middle of the ventral surface. The two or three nearest the midline on each side of the ventral surface point in. An idea of the general structure of this cercaria can be gained from the figure.

Cysts of *Cercaria rubra* were large and thick walled. The worm almost completely fills the cyst and moves only slightly. Worms were freed from the cysts and their structure studied (Fig. 7a and 7b). Most typical is the arrangement of the spines in the anterior collar. There are forty-three spines of uniform size arranged in two alternate rows. The four on each side nearest the midline of the ventral surface point inward.

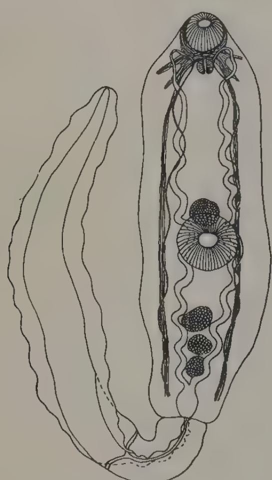

Fig. 8.—Mature *Cercaria reflexae,* ventral view. Cystogenous glands not shown. X 88.

As an appendix to the Echinostome cercariae I treat the following form: The livers of eight out of thirty-eight specimens of *Lymnaea reflexa* Say, from Chicago, contained rediae in which were developing a species of cercaria, for which the name *Cercaria reflexae* is proposed. Also in the body cavities of a number of the same snails were encysted cercariae of the same species.

Cercaria reflexae (Fig. 8) agrees with the echinostomes in the general structure of the redia, and in the method of locomotion and structure of the excretory and digestive systems of the cercaria. However,

it lacks entirely the anterior collar and crown of spines typical of the echinostomes. No record has been found of any species, either cercaria or adult, that corresponds in structure to this species.

Microcercous Cercariae

The group of microcercous cercariae includes a very heterogeneous collection. Some of them develop in rediae and some in sporocysts. Some have stumpy tails developed as suckers and some have merely blunted tails. Dollfus (1913) has already formed within this group a subdivision, the Cotylocercous cercariae, which contains a number of marine forms, centering around *Cercaria pachycerca* Diesing, with

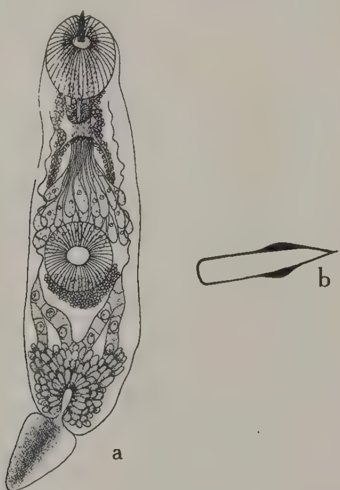

Fig. 9.—Mature *Cercaria trigonura*, (*a*) ventral view. X 260. (*b*) Stylet of same. X 866.

their tails developed as suckers. Whether there is any close relationship between the members of this group and the other forms now included within the microcercous cercariae is impossible to determine in the present state of our knowledge. It is therefore best to retain the name microcercous cercariae provisionally to cover all short-tailed forms which do not fit into other groups.

Such a cercaria was found in four out of the thirty-six specimens of *Campeloma subsolidum* from Hartford, Conn. The tissues of the body above and at the bases of the gills of these snails contained large numbers of free mature cercariae. There were also present rediae in

different stages of development in which only little differentiated germ balls could be distinguished.

This cercaria (Fig 9 a), for which I propose the name *Cercaria trigonura,* has an elongate cylindrical body and a very short heart-shaped tail. It is unable to swim freely in open water, but extends and contracts its body very rapidly. The tail bent ventrad and pushing against the substratum aids somewhat in locomotion and the oral sucker at times becomes attached. By this peculiar method the animal is able to make a little progress with a great deal of effort.

On the ventral surface of *Cercaria trigonura,* just at the base of the tail, is a slit-like opening, which extends forward a short distance and dorsad reaches up into the body. Opening into the cavity thus formed are large numbers of unicellular glands which stain very heavily with hematoxylin. The position and structure of this posterior gland suggests that it may function for adhesion. No activity which suggests such a function has been observed. Figure 9a shows the characteristic shape of the stylet of this species. The large bicornuate excretory vesicle lined with a layer of granular cuboidal epithelial cells is also characteristic.

Cercaria trigonura is unique among the microcercous cercariae in having a large posterior gland opening at the base of the tail and in its bicornuate excretory bladder. It differs from all except *Cercaria limacis* Moulinié (1856: 83, 163-164), in having a blunted tail which is not modified as a sucker.

Furcocercous Cercariae

The Furcocercous or forked-tailed cercariae are very imperfectly known. Although at least a dozen species have been reported as distinct, the anatomy of only a few of them is at all well worked out and the life history of no one of them has been determined.

Tangled masses of sporocysts containing a cercaria of this type were found in the livers of five out of the thirty-six specimens of *Lymnaea reflexa* from Chicago. The name *Cercaria douthitti* is proposed for this form. The sporocysts are long cylindrical tubes of varying caliber which are unbranched and very much tangled together. When the cercariae were freed from the sporocysts they moved around somewhat erratically by a vigorous vibration of the body and tail. The oral sucker was not fully developed, so that the creeping movement could not be accomplished.

Cercaria douthitti (Fig. 10) is a small cylindrical cercaria with eyespots and a tail considerably longer than its body. Although it has no stylet, the region back of the acetabulum is almost completely filled with eight large unicellular glands, which seem to be analogous to the

stylet glands in certain other forms. Two groups of ducts from these glands run forward along each side and pass through the oral sucker to open at the anterior tip.

Only one forked-tailed cercaria, *Cercaria ocellata* La Valette St. George (1855: 22-23), resembles at all closely in structure *Cercaria douthitti*. *Cerceria ocellata* is, however, almost twice as large as my species and has fin-like projections on the divided lobes of the tail.

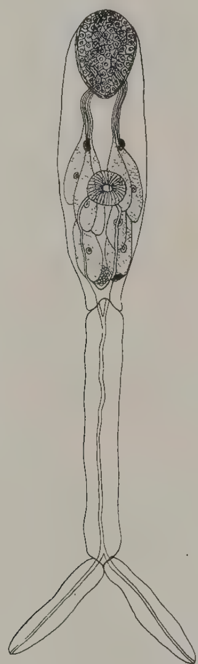

Fig. 10.—Mature *Cercaria douthitti,* ventral view. X 195.

Xiphidiocercariae

About one-third of all the known cercariae belong to the Xiphidio- or stylet cercariae. They are characterized as slender-tailed distome cercariae with a boring spine. As this group contains a large variety of forms, numerous subdivisions have been proposed. In my material are found five new stylet cercariae of four different types. Two of them are so much alike and agree so closely with several European cercariae that it is proposed to unite them into a new subgroup, which will be discussed next.

Polyadenous Cercariae

The name Polyadenous cercariae is proposed as a group designation for those of the Xiphidiocercariae which agree in the following characters.

1. Development in much elongate sac-shaped sporocysts.

2. Tail slender and except when much extended less than body length.

3. Acetabulum back of the middle of the body and smaller than the oral sucker.

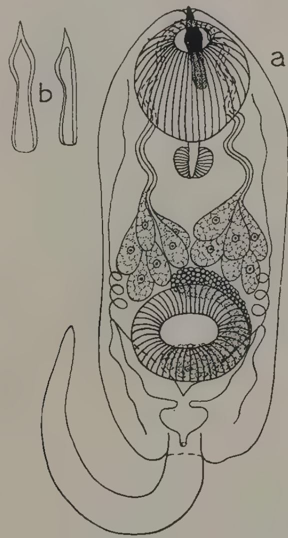

Fig. 11.—Mature *Cercaria isocotylea;* (*a*) ventral view. X 415. (*b*) Stylet of same. X 577.

4. Stylet about 0.030 mm. in length, six times as long as broad, and with a thickening about two-thirds of the distance from the base to the point.

5. Stylet glands six or more on each side between the acetabulum and the pharynx.

6. Excretory bladder bicornuate.

Two European fresh-water cercariae, *Cercaria limnaeae-ovatae* von Linstow, and *Cercaria secunda* Ssinitzin, can without question be placed in this group. I am able to add two American species, *Cercaria isocotylea* and *Cercaria polyadena.*

Cercaria isocotylea (Fig. 11a) was found in elongate, must twisted cylindrical sporocysts in 18 per cent. of 170 specimens of *Planorbis*

trivolvis from a drainage ditch northeast of Urbana, Ill. This cercaria moves actively both by swimming in open water and on a surface where it creeps with the aid of the suckers. When swimming, the body, which is turned with the dorsal side down, is bent slightly ventrad and the tail, which moves almost in a vertical plane, lashes rapidly. The locomotion is not very rapid and somewhat erratic.

This cercaria, except when much extended, is under 0.20 mm. in length. The tail is considerably shorter than the body and very slender. The acetabulum is almost as large as the oral sucker. The character-

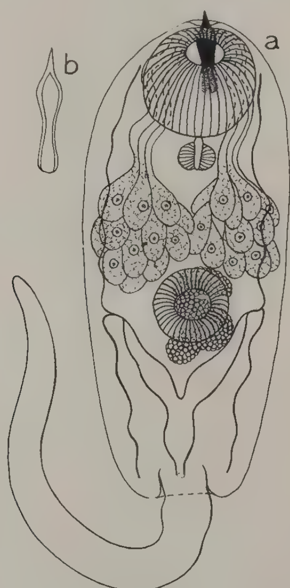

Fig. 12.—Mature *Cercaria polyadena;* (*a*) ventral view. Cystogenous glands not shown. X 415. (*b*) Stylet of same. X 577.

istic stylet is shown in Figure 11b, and the stylet glands form two groups of from six to eight in a group.

Cercaria polyadena (Fig. 12a), the second polyadenous form, was found in one of the specimens of *Lymnaea reflexa* from Chicago, which was also infected with *Cercaria reflexae.* The cercariae were contained in elongate unpigmented sporocysts, much like those of the former species. The movement of this cercaria is much like that of *Cercaria isocotylea,* and its stylet (Fig. 12b) is very similar to that of that species. It has, however, a larger body and tail, a smaller acetabulum and a larger number of stylet glands than *Cercaria isocotylea.*

Some facts are known of the further development of the polyadenous cercariae. *Cercaria limnaeae-ovatae* has been assigned to *Opisthioglyphe rastellus* (Olson), and Ssinitzin (1905) suggests that *Cercaria secunda* may be the larva of a *Plagiorchis* species. It is possible, therefore, that the American forms belong to Lühe's subfamily *Plagiorchiinae*.

Microcotylous Cercariae

Lühe's group of Cercariae microcotylae contains a number of very small Xiphidiocercariae, most of which are very insufficiently known. Besides the forms listed by Lühe (1909: 196-198) and *Cercaria caryi*,

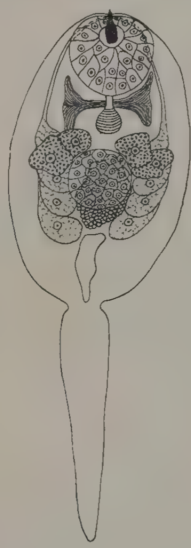

Fig. 13.—Immature *Cercaria leptacantha*, ventral view. X 433.

three Egyptian cercariae of Looss (1896: 227-232), *Cercaria cellulosa* sp. inq., *Cercaria pusilla* sp, inq. and *Cercaria exigua* sp. inq., should be placed in this group. An American species to be called *Cercaria leptacantha* is added from my material. The tissues above the gills in three of the thirty-six specimens of *Campeloma subsolidum* from Hartford, Conn., was infected with oval thin-walled sporocysts containing cercariae of this species.

The general structure of *Cercaria leptacantha* is shown in Figure 13. None of the cercariae were fully matured and but slight movement was noted.

Cercariae Ornatae

Lühe (1909: 190) defines the Cercariae ornatae as follows: "Distome Cercariae mit Bohrstachel, deren schlanker Ruderschwanz einen Flossensaum besitzt."

In this group are placed *Cercaria ornata* La Valette, and *Cercaria prima* Ssinitzin. From my material an American form, *Cercaria hemilophura,* is added. This group must very evidently be considered as merely provisional, since the three cercariae comprising it are very different in structure, having little in common except the presence of a fin-like projection from the tail.

A tangled mass of elongate, orange-pigmented sporocysts containing cercariae of *Cercaria hemilophura* were found in one of twenty

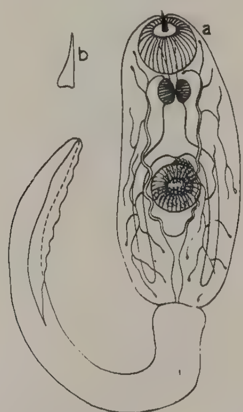

Fig. 14.—Mature *Cercaria hemilophura;* (*a*) ventral view. Cystogenous glands not shown. X 140. (*b*) Stylet of same. X 433.

specimens of *Physa gyrina* from Rockford, Ill. The sporocyst tubes do not branch and are of varying caliber. Club-shaped ends jut out from the mass and sway slightly backward and forward.

Cercaria hemilophura (Fig. 14a) is a large cercaria, over 0.40 mm in well-extended specimens, and its tail is about the length of the body. Along the ventral surface of the posterior half of the tail extends a fin-like projection which at its widest is about half the width of the tail. The stylet (Fig. 14b) is small, tapers regularly to a point and has no thickened region. The body contains large numbers of cystogenous glands, but no stylet glands could be distinguished. Other points of general structure can be made out from the figure.

The livers of three out of ninety-three specimens of *Physa anatina* from Manhattan, Kan., contained sausage-shaped sporocysts in which a peculiar kind of Xiphidiocercaria was developing. For this species the name *Cercaria brevicaeca* is proposed. No cercaria has been found in the literature which corresponds closely to this form.

The specimens of *Cercaria brevicaeca* examined moved clumsily and irregularly while swimming. Figure 15a shows the general points of structure. Very characteristic of this species is the stylet (Fig. 15b). Of the excretory system only the peculiarly shaped vesicle can be made out. This is composed of a pyriform median portion and two lateral parts which almost completely surround the acetabulum. Numerous cystogenous glands and two clumps of from ten to twelve stylet glands are present.

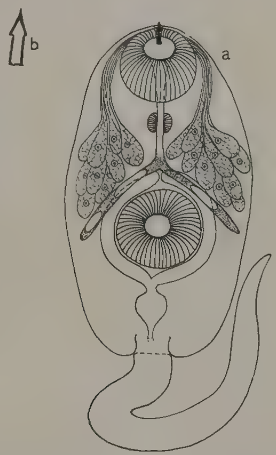

Fig. 15.—Free-hand drawing of *Cercaria brevicaeca;* (*a*) ventral view. Cystogenous glands not shown. X 150. (*b*) Stylet of same. X 433.

SUMMARY

Fourteen new cercariae were found in six species of fresh-water snails obtained from seven localities.

Of these one is a monostome, two are amphistomes and the others belong to five of the groups under the distomes.

Observations on the living cercariae show interesting locomotor activities.

The two amphistome cercariae described correspond closely in structure to *Diplodiscus temporatus* Stafford. Two different cercariae, one a large gymnocephalous form and the other a small stylet cercaria, which Cary described as being this species cannot belong to it.

A new subgroup of gymnocephalous cercariae, the megalurous or heavy tailed cercariae, is proposed; it includes *Cercaria megalura* from *Pleurocera elevatum* and *Cercaria distomatosa* Sonsino.

Cercaria polyadena and *Cercaria isocotylea* are made the basis of the polyadenous cercariae, a new subgroup of the xiphidiocercariae.

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NEW VARIETIES AND SPECIES OF MALARIA PLASMODIA *

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Although it has been nearly twenty-four years since Laveran announced his discovery of the parasites concerned in the etiology of the malarial fevers, and although an immense amount of work has been expended on the study of these parasites in the endeavor to arrive at a classification of them that can be accepted by all observers, we are still far from achieving that happy result, as is readily evident if one compares the classifications given by the authors of the most recent works on the subject. While most authorities agree that there are at least three species of malaria plasmodia, they do not all agree as regards nomenclature, and Laveran still adheres to the belief in the unity of all malaria plasmodia occurring in man, regarding the so-called species as variations in a single pleomorphous species.

In view of the evidence that has accumulated regarding the morphology, life cycle and relation to disease of the plasmodia of malaria, I believe, with most investigators, that several species of malaria plasmodia exist. The marked differences in the morphology of the species generally accepted, which are constant; the length of their cycle in man; the symptoms produced by their presence and the periodicity of the occurrence of these symptoms, all point to the conclusion that we are dealing with different species, while the fact that each plasmodium reproduces its kind when experimentally inoculated into man and with that reproduction gives rise to the characteristic clinical symptoms commonly produced by the species inoculated, makes the evidence in favor of distinct species practically conclusive. When to these evidences is added the fact that certain species of mosquitoes can only transmit certain species of the plasmodia, the evidence would appear to be incontrovertible.

As a matter of fact, Laveran is practically alone in his advocacy of the unity of the human malaria plasmodia, for the consensus of opinion among protozoologists is in favor of the plurality of species. While this is so, there is still considerable disagreement regarding the number of species which should be recognized and the classifications

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of Grassi and Feletti (1890), Mannaberg (1899), Sacharoff (1896), Lühe (1900), Schaudinn (1902), Doflein (1911) and others differ somewhat in this respect, although the majority recognize at least three species, the tertian, quartan and estivo-autumnal plasmodia. The names given these species also vary with different authorities, but if the generally accepted rules of nomenclature be followed, the tertian plasmodium must be called *Plasmodium vivax* (Grassi and Feletti), the quartan, *Plasmodium malariae* (Marchiafava and Bignami), and the estivo-autumnal, *Plasmodium falciparum* (Welch). While, as has been stated, nearly all authorities admit the existence of the three species mentioned, there is still considerable discussion regarding the existence of still other species, especially of species of the estivo-autumnal plasmodium. By many observers the plasmodia encountered in the malarial fevers generally known as estivo-autumnal are divided into two species, the subtertian or tertian, and the quotidian, while by some the latter is divided into a pigmented and unpigmented quotidian plasmodium.

During the past sixteen years I have had the opportunity of studying the plasmodia in thousands of cases of estivo-autumnal malaria and have reached the conclusion that two distinct species of plasmodia are concerned in the etiology of these forms of malarial fever, one sporulating in twenty-four hours, the other in forty-eight hours. These two species of plasmodia were first described by Marchiafava and Bignami, and there is no doubt in my mind that they can be distinguished morphologically and that, in uncomplicated instances of infection, they each produce a characteristic form of malarial fever. In previous communications (1901, 1909) I have described in detail the morphology and life cycle of these plasmodia and the symptoms produced by infection with them, and further research has only convinced me of the truth of Marchiafava and Bignami's classification of the estivo-autumnal plasmodia. Later (1909a) I proposed the name *Plasmodium falciparum quotidianum* for the quotidian species of the estivo-autumnal plasmodium, considering it a subspecies of the subtertian or tertian estivo-autumnal plasmodium, or *Plasmodium falciparum*. Accordingly, at the present time, I believe that there are four well-defined species of malaria plasmodia, namely, *Plasmodium vivax*, the tertian; *Plasmodium malariae*, the quartan; *Plasmodium falciparum*, the subtertian or tertian estivo-autumnal, and *Plasmodium falciparum quotidianum*, the quotidian estivo-autumnal.

Recently there have appeared contributions by two different observers describing new varieties or species of the malaria plasmodia. In view of the interest which must attach to the discovery of any new forms of these parasites in man, and as I believe that I have observed

plasmodia similar in every respect to those described in the contributions mentioned, it has seemed of importance to place my observations on record together with some critical comments regarding the subject. In April, 1914, in the *Proceedings of the Royal Society* and in the *Annals of Tropical Medicine and Parasitology*, J. W. W. Stephens (1914, 1914a) described what he considered a new species of malaria plasmodia of man, while in May, 1914, in the *Bulletin de la Société de Pathologie Exotique*, Ahmed Emin described (1914) a plasmodium which he regarded as a variety of *Plasmodium vivax*, the benign tertian plasmodium. Stephens has named the plasmodium observed by himself *Plasmodium tenue*, while Emin has named his *Plasmodium vivax* variety *minuta*. Both contributions are well illustrated by presumably correct drawings of the plasmodia described, else I would not feel justified in discussing the parasites, not having seen the actual preparations containing them. However, as I have repeatedly observed plasmodia answering in every detail to those described and illustrated in the papers referred to, I feel no hesitation in recording my observations in confirmation of the existence of these forms, although I cannot agree with all that is noted regarding the so-called *Plasmodium tenue* in so far as its classification as a new species is concerned. The plasmodium described by Ahmed Emin will first be considered.

PLASMODIUM VIVAX VARIETY MINUTA

This plasmodium was observed in the blood of pilgrims in the hospital at Camaran, an island in the Red Sea, about 30 miles from Hodeidah. Emin describes the plasmodium as resembling the benign tertian plasmodium (*Plasmodium vivax*), but differing from it principally in its smaller size, lack of enlargement of the infected erythrocyte, and smaller number of spores or *merozoites*. The pigment present in the plasmodium is fine and resembles that in *Plasmodium vivax*. At the time of sporulation the plasmodium almost entirely fills the erythrocyte, which is not enlarged, and from four to ten merozoites are produced by the division of the parasite. Ameboid motility is slight as compared with that of *Plasmodium vivax*. Multiple infection of the erythrocyte was not infrequently observed, and one of the drawings shows an erythrocyte containing as many as five schizonts in the "ring" stage of development. Emin believes that while there are marked differences between this plasmodium and *Plasmodium vivax*, it resembles the latter to such an extent that it should properly be regarded as a variety rather than a new species, and proposes the name *Plasmodium vivax* variety *minuta*.

In 1899 and 1900, while studying the malaria plasmodia observed in the blood of our soldiers returning from the Philippines, at the

U. S. Army General Hospital, Presidio of San Francisco, Cal., I observed a plasmodium in the blood of six patients answering to the description of the variety *minuta* of Emin, and my observations were published in the Report of the Surgeon-General of the Army (Craig, 1900). Emin's description of his plasmodium answers almost exactly to that of the plasmodia observed in these cases, and his drawings are accurate reproductions of the plasmodia that I observed. Since that time I have noted the same plasmodium in regions where only tertian infections are present, and I am in agreement with him in considering it to be a variety of *Plasmodium vivax*. The following is my original description of this plasmodium, as published in the Surgeon-General's Report:

"In studying the blood of soldiers returning from the Philippines and suffering from malaria, I have noticed in several cases a peculiar form of the malarial parasite which I have classified in reporting on the cases as a tertian parasite, but which presents so many differences from the ordinary tertian parasite as to indicate that it is a distinct variety of the plasmodium.

"I have invariably observed it in the blood of patients having tertian paroxysms and always in large numbers. All stages of the parasite have been observed, from the hyaline disks to the segmenting bodies. It appears first as a very highly refractive circular hyaline disk within the erythrocyte, having a sharply cut outline and no ameboid motion. The absence of ameboid motion differentiates it from all other young forms of the malarial parasites. The hyaline disk is about one-fourth the size of the infected corpuscle, which is normal in size and appearance.

"In a few hours the hyaline disk has grown to about one-half the size of the corpuscle which contains it and has become pigmented. The pigment exactly resembles that found in the ordinary tertian parasite, being finely granular and motile and distributed unequally throughout the parasite. The parasite is circular in shape and devoid of ameboid motion. The border of the parasite is very sharply defined and the protoplasm very refractive and sometimes finely granular. The infected corpuscle is unaltered in size and color and is not crenated or shrunken.

"In about thirty-eight to forty hours the parasite has nearly filled the corpuscle containing it, and the amount of pigment has increased. The parasite is circular in shape and presents the same refractive protoplasm and sharply cut border; the pigment is sluggishly motile, reddish in color and in the shape of fine granules. The infected corpuscle is normal in size and color.

"I have not as yet observed the presegmenting forms in the blood, but have seen several segmenting forms. These are much smaller than the ordinary tertian segmenting forms, and the greatest number of segments observed has been ten. The segments are oval in shape or perfectly round, sharply cut and refractive. The pigment is usually collected in a solid reddish-brown mass at the center of the segmenting parasite and is immotile."

After giving the differential points between this parasite and the other species of malaria plasmodia, consisting chiefly in size, shape, ameboid motility, number of merozoites and character and arrangement of the pigment, I call attention to the fact that "The differentiation of this parasite from the quartan organism is really much more difficult than is the case with the tertian or estivo-autumnal plasmodia. Indeed, I mistook them for quartan parasites until the clinical histories of the cases and certain peculiarities of the parasites caused me to study them more carefully." They differ from *Plasmodium malariae* in the lesser degree of ameboid motility, in the larger amount of and more finely granular pigment, and in having a human life cycle of forty-eight hours instead of seventy-two hours. In conclusion, I state:

"I believe that this parasite is either a distinct variety of the malaria plasmodia or that it is a tertian parasite which has acquired the characteristics described through some unknown condition of environment acting on the development of the organism."

It will be noted that in my original description I mention that ameboid motility was absent in this plasmodium, but further observations have proved that it is present, but very much less pronounced than in *Plasmodium vivax*. The round form of this plasmodium is well illustrated in Emin's drawings and the number of merozoites mentioned by him, four to ten, agrees exactly with my own observations, the largest number I have ever noted being ten. My original description was based on the living organisms, but later observations on specimens stained with Wright's modification of the Romanowsky stain confirm Emin's description of the stained plasmodium. The chromatin stains very intensely and tends to collect near the periphery of the plasmodium after the latter is half grown and just before sporulation, while the pigment at this time collects at or near the center of the plasmodium, the merozoites frequently being arranged regularly around the mass of pigment, giving the plasmodium the typical daisy or "marguerite" appearance, often spoken of as being characteristic of the sporulating forms of *Plasmodium malariae*.

Emin states that he could not be sure whether Schuffner's dots occurred in the infected erythrocyte, but in my experience they do

occur, but much less frequently than in the case of erythrocytes infected with *Plasmodium vivax,* and the dots are smaller and less in number. I believe that those who have reported Schuffner's dots as occurring in erythrocytes infected with the quartan plasmodium (*Plasmodium malariae*) have really been observing the variety *minuta* of *Plasmodium vivax,* for it is with the quartan plasmodium that this plasmodium is most apt to be confused. Indeed, the resemblance of this variety of the tertian plasmodium to the quartan, so far as morphology goes, is much greater than it is to the tertian plasmodium, but the fact that the parasite is found only in cases having a tertian periodicity, together with the character of the pigment and its arrangement, definitely separates it from *Plasmodium malariae,* and demonstrates that it is closely related to the tertian plasmodium. In the stained preparations the fine pigment, the characteristic arrangement of the chromatin and the absence of "band forms" serve to distinguish this variety of *Plasmodium vivax* from *Plasmodium malariae,* but unless one is well acquainted with the morphology of the latter plasmodium this variety of the tertian parasite will almost certainly be confused with it.

The occurrence of all stages of development in the peripheral blood is sufficient to differentiate this plasmodium from either *Plasmodium falciparum* or *Plasmodium falciparum quotidianum,* while the large size of the organism and its general morphology definitely proves that it does not belong to either of these species.

From my own observations, which are confirmed by those of Emin, I believe that this plasmodium should be considered a variety of *Plasmodium vivax,* and that it should be known by the name given it by Emin, that is, *Plasmodium vivax* variety *minuta.* I do not believe that the evidence is sufficient to prove that it is entitled to specific rank.

PLASMODIUM TENUE

In two identical contributions published separately, Stephens (1914, 1914a) describes what he considers a new species of malaria plasmodium. This so-called species is described from the parasites observed in a single blood-slide sent Stephens by Major Kenrick, I.M.S., from Pachmari, Central Provinces, India. Both of the contributions are illustrated with the same drawings and demonstrate conclusively that the plasmodia present in this slide are all in practically the same stage of development, so that the species is described from only one stage of development, and that an early stage, before the development of pigment. This parasite Stephens has named *Plasmodium tenue,* and he states that he believes that it has affinities with the simple tertian plasmodium and with *Plasmodium canis* of the dog, rather than with the malignant tertian parasite.

Basing his deductions entirely on the stained preparation, Stephens considers the distinguishing features of this species to be extreme ameboid activity, scanty cytoplasm, and an amount of nuclear chromatin out of proportion to the volume of the parasite. The extreme ameboid activity is evidenced by the marked variations in the shape of the parasite, ring forms being rare, while the vast majority of the organisms present long, thin processes stretching across the infected erythrocyte, frequently multiple in number. The small amount of cytoplasm is contained within these filamentous processes. The nuclear chromatin appears out of proportion to the volume of the plasmodium, occurring in the form of rods, strands, forked masses, patches, etc. The chromatin is situated in the protoplasmic processes either as strands, rods or angular masses situated at the junction of the two processes. Stephens says: "Abundance of and marked irregularity in the distribution of the chromatin masses are characteristic of this parasite."

Stephens considers that this plasmodium differs from the malignant tertian plasmodium (*Plasmodium falciparum*) in possessing greater ameboid activity and in the abundance and irregularity of the nuclear chromatin, and from the simple tertian plasmodium (*Plasmodium vivax*) in being smaller, having more delicate ameboid processes, a larger amount of and more marked irregularity in the distribution of the chromatin, and in the rarity of typical "ring" forms.

From the description of this organism given by Stephens and the drawings which accompany the description, it is, to say the least, extremely doubtful if this parasite can be accepted as a new species of malaria plasmodium. Even though it differed from the known species to a much greater extent than is described, it would be entirely unjustifiable to describe it as a new species from the morphology of the parasite during only a small portion of the life cycle and from the organisms observed in a single stained blood-smear. The morphological details on which the species is based are inadequate to establish the species, especially as the plasmodium is undoubtedly in that stage of development, the young unpigmented stage, in which a differential diagnosis from *Plasmodium vivax* would be most difficult. As a matter of fact, Stephens states that he is in doubt as to whether Schuffner's dots occur in the infected erythrocyte, but admits finding one infected erythrocyte which was enlarged and showed Schuffner's dots. Regarding the morphology of the plasmodium observed in this erythrocyte, Stephens says: "Although I could detect no pigment in this parasite I was not otherwise able to distinguish it from a simple tertian parasite."

Admitting, as I believe nearly every protozoologist will, who has had an extensive experience with the plasmodia of human malaria, that the classification of this organism as a new species is not justified, owing to the fact that practically only one stage of development has been observed and that the morphological characteristics are not sufficient to base a species on, the question remains as to the exact position of this plasmodium which appears to possess some peculiarities not usually described for the well-known species of human plasmodia. From my own experience, I am convinced that all of the species of malaria plasmodia present at times, and from unknown or known causes, atypical generations, so far as morphology are concerned, and if specimens of blood containing such plasmodia be studied to the exclusion of others from the same infection, one is most apt to regard these plasmodia as varieties or new species. Time and again I have been on the point of describing such atypical plasmodia as new species and have only hesitated because of previous experience with similar forms. In many of the patients showing these atypical plasmodia continued observation has demonstrated that the atypical forms were replaced by typical examples of one of the well-known species, while in other instances a minute examination of the preparations would show that, while the atypical plasmodia were the most numerous, typical parasites of one of the recognized species did occur, though perhaps in very small numbers.

As regards the parasite described by Stephens as *Plasmodium tenue,* I may say that I have several times encountered exactly similar parasites, so far as I can determine from his description and drawings, in undoubted infections with *Plasmodium vivax,* and for this reason I believe that Stephens' plasmodium is a rather atypical form of *Plasmodium vivax* in the unpigmented stage of development. As claimed by Stephens, the evidence of ameboid activity is pronounced, but no more so than is frequently observed in preparations of blood containing *Plasmodium vivax* at a corresponding stage of development, while the extreme delicacy of the cytoplasmic pseudopodia is frequently observed in tertian infections in which quinin has been administered in insufficient dosage to kill the plasmodia, but sufficient to produce a stimulation of ameboid activity and consequently a greater number of cytoplasmic processes. The amount of chromatin present in Stephens' plasmodium is greater than is usually observed at this stage of development, but not greater than I have observed in plasmodia in undoubted infections with *Plasmodium vivax,* in which the parasites were in the same stage of development. At this stage of development the infected erythrocyte is very frequently not enlarged in infections with the ordinary tertian plasmodium, so that the lack of enlargement of the eryth-

rocyte is not a point in favor of a new species. As a matter of fact, the distortion in the shape of many of the infected erythrocytes, as shown in Stephens' drawings, is very characteristic of tertian infections, and the fact that the erythrocyte containing the single organism observed in a later stage of development (an organism which Stephens states he was unable to distinguish from *Plasmodium vivax* except for the absence of pigment) was enlarged and presented Schuffner's dots, is certainly good evidence that this parasite is a more or less atypical form of the ordinary tertian plasmodium, or *Plasmodium vivax*.

The reasons underlying the production of morphologically atypical generations of malaria plasmodia are obscure, but I am convinced that insufficient dosage with quinin, and perhaps with other drugs, often leads to the production of such plasmodia and that these plasmodia may retain for several generations morphological abnormalities produced by adverse agencies, either physical or chemical. We know that in the case of *Entamoeba histolytica* the character of the nucleus is absolutely changed by the administration of drugs that produce a cessation of the acute symptoms of dysentery, and there is no reason why the same should not occur in the instance of the malaria plasmodia. So marked are the changes produced in the morphology of *Entamoeba histolytica* by either chemical or physical conditions leading to the cessation of acute symptoms that the form of the parasite occurring when the dysenteric symptoms abate was long regarded by the best protozoologists as a distinct species of entameba, and I believe that it is only reasonable to admit that the same influences may cause atypical generations of the malaria plasmodia.

In proof of this assertion I may state that I have followed infections in which the plasmodia were very atypical, being modified morphologically by the exhibition of small doses of quinin, and have seen a return to normal morphology when the drug was discontinued. One of the most common effects of quinin is a great stimulation in the ameboid activity of the malaria plasmodia and an apparent stimulation in the division of the chromatin, as evidenced by the presence of delicate pseudopodia containing an abnormal amount of chromatin during the early stages of development of the plasmodia. I would not wish to be understood as claiming that this is the explanation of the morphology of the parasite discussed in this instance, but I am satisfied that *Plasmodium tenue* is an atypical form of *Plasmodium vivax*. I have observed identical forms, so far as can be judged from the description and drawings, not once, but a considerable number of times, in supposedly untreated infections with *Plasmodium vivax*, and many times in infections with this plasmodium after the exhibition of doses of quinin insufficient to kill the plasmodia.

However, whether or not this parasite is identical with *Plasmodium vivax*, it cannot be accepted as a new species until the morphology of the parasites during the entire human life cycle at least is studied, for the only claim it now has to specific rank is the presence of slight differences in morphology during a very limited portion of the human life cycle, that is, the early unpigmented stages of development when such differences are commonly observed even in the well-recognized species of plasmodia.

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THE POISON GLANDS OF THE LARVA OF THE BROWN-TAIL MOTH

(EUPROCTIS CHRYSORRHOEA LINN.)

Cornelia F. Kephart

It is well known that certain lepidopterous larvae possess urticating hairs which are the cause of a more or less severe and painful irritation when they come in contact with the human skin. In this country, the one which has attracted the most general attention on this account is the larva of the imported brown-tail moth, *Euproctis chrysorrhoea.* A great many cases of poisoning have been attributed to this species, and one death has been reported as the result of severe internal poisoning caused by inhaling the hairs.

There has been much discussion among scientists as to whether the effect of these hairs is purely mechanical or whether they are actually poisonous, but on the other hand, singularly little definite study has been made of the morphology of the hairs and their underlying structures. It was for this reason that the subject of this paper was suggested by Dr. W. A. Riley and to him the writer is greatly indebted for much kindly criticism and many helpful suggestions.

In 1894 Packard described the poisonous spines of *Lagoa crispata,* stating that the spines themselves were secreted by certain large trichogen cells lying under the rest of the hypodermis and connected with the spines through pore canals in the cuticle. In addition to these cells there were other smaller ones lying in different places above and below the hypodermis, and even in the pore canal itself, which he called "poison nuclei," and which he claims secrete the poison. Ingenitsky (1897) studied several different forms, especially *Ochneria monacha* Linn., and he clearly demonstrated that there are two cells connected with each hair and that the smaller of the two is the trichogen cell, which, after secreting the hair, decreases in size, and that the large cell is the actively secreting poison gland. Aside from the fact that Ingenitsky carefully traced the development of the two cells through all stages of the larva, this view would seem to be the reasonable one, because one would naturally expect to find that the actively secreting cell was larger than one that had already stopped its action. This latter is the same view as that expressed by Holmgren (1895). He also found that the poison hairs were connected with two cells, one somewhat larger than the other, one of which secreted the hair and the other the poison.

In all the forms studied by the different authors, however, the hairs were one of two general types. The first is a simple hair tapering from the base to the tip and containing a poisonous substance, the exact nature of which is not known. When one of these hairs comes in contact with the skin the point breaks off and the contents are liberated in the blood.

The second type is practically the same except that the tip of the hair is in the form of a more heavily chitinized cone which is fitted, cap-like, on the end of the hair and which is readily detachable. In this instance the hair remains on the larva, the tip only breaking off and entering the skin. This type occurs most frequently on the so-called slug caterpillars. These hairs are also said to contain poison, although there has been no evidence brought forward so far to prove that their action is anything more than that of a mechanical irritant.

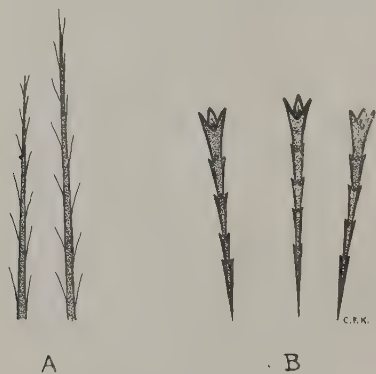

Fig. 1.—Hairs of a larva of *Euproctis chrysorrhoea*. *A*. Ordinary hairs. X 13. *B*. Poison hairs. X 300.

The poison hairs of the brown-tail caterpillar are of a very different type (Fig. 1, B). They are pointed at the base, gradually enlarge toward the tip and have three rows of barbs extending their entire length. They are heavily chitinized, and are filled with a granular substance similar in appearance to the contents of the underlying hypodermal cells. These hairs are found only on the subdorsal and lateral tubercles (Fig. 2, *sdt* and *lt*), arising in bunches of from three to twelve on minute papillae with which the tubercles are thickly covered (Fig. 3, *pap*). Tyzzer (1907) claims to have found as many as twenty on a single papilla, but the writer has not found more than twelve, five to seven being the usual number. They are 70 microns to 100 microns in length and 4 microns to 5 microns in thickness at the larger extremity.

There has been considerable doubt in the minds of many entomologists as to whether the hairs were really poisonous or whether they acted merely as mechanical irritants, but the experiments of Dr. E. E. Tyzzer seem to indicate that there is some specific poison in the hairs.

He found that if one of the nettling hairs be introduced into a drop of blood a peculiar change takes place in the red blood-corpuscles. To quote from his report: "They at once become coarsely crenated, and the rouleaux are broken down in the vicinity of the hair. The corpuscles decrease in size, the coarse crenations are transformed into slender spines which rapidly disappear, leaving the corpuscles in the form of spheres, the light refraction of which contrasts them strongly with the normal corpuscles. The reaction always begins at the basal sharp point of the hair. Minute particles of glass wool, the barbed

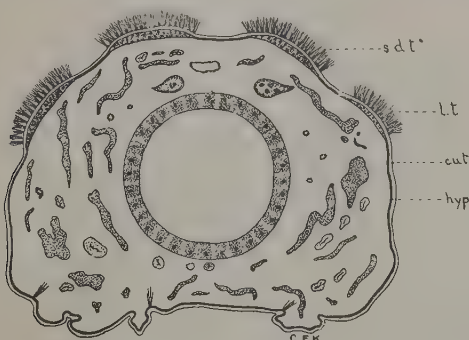

Fig. 2.—Cross section of a larva of *Euproctis chrysorrhoea* showing distribution of poison hairs; *sdt,* sub-dorsal tubercle; *lt,* lateral tubercle; *cut,* cuticle; *hyp,* hypodermis.

hairs of a tussock moth, and the other coarser hairs of the brown-tail, all failed to produce any effect on the red blood-corpuscles." These experiments I have repeated with the same results.

Dr. Tyzzer then tried the effect of heating on the activity of the hairs and found that after baking them for an hour at 110 C. they still gave a typical reaction with the red blood-corpuscles and produced the typical dermatitis when rubbed on the skin. But he found that after baking for an hour at 115 C. they failed to react on the corpuscles, and when rubbed on the skin produced only a slight redness and irritation, such as is caused by any foreign body penetrating the epidermis. All these facts seem to show that there is a definite poisonous substance either in or on the hairs.

He next tried a number of reagents to determine the solubility of the irritating substance. He found that acetone, alcohol, chloroform

and ether had no effect on the reaction of the hairs, whether they were boiled in it or left for days at room temperature. I have found, however, that the hairs from caterpillars that had been kept for five weeks in 70 per cent. alcohol failed to have any effect on the red blood-corpuscles, while those from the cast skins of larvae which had been kept in a dry place for several months produced the characteristic reaction when introduced into a drop of blood. "The nettling hairs remain active after being boiled in pyridin, which boils at a temperature between 106 and 108 C. They also remained active when kept for several days in glacial acetic acid, in 0.5 per cent. acetic and in both 1 per cent. and 0.1 per cent. HCl." But when they were left over night in 1 per cent. and 0.1 per cent. solutions of KOH and NaOH they failed to react either on the skin or on the red blood-corpuscles.

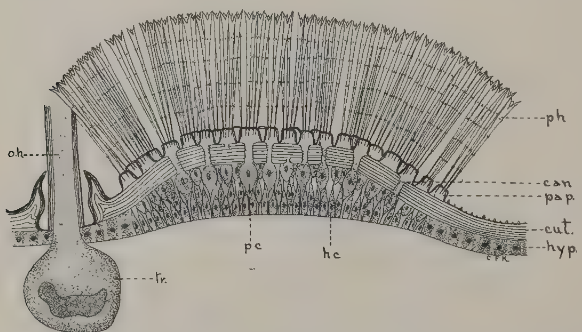

Fig. 3.—Enlarged section of a tubercle; *oh*, ordinary branched hair; *tr*, trichogen cell; *ph*, poison hair, *can*, pore canal; *pap*, papilla; *pc*, poison-secreting cell; *hc*, hair formative cell; *cut*, cuticle; *hyp*, hypodermis. Studied under low power, arrangement of cells semidiagrammatic.

This difference in the action of the weak acids and the weak alkalies is not surprising, since the blood fluid is itself alkaline and the poison is soluble in it.

The next question which arises is whether the poisonous substance is contained in the hair or is merely smeared on the outside, as a number of writers suggest.

If it is on the inside there must be a pore, or opening, of some kind in the point of the hair, because, as has already been stated, the reaction of the red blood-corpuscles always begins around the basal point of the hair and gradually spreads from there, except in the instances where the hair has been broken, when the action takes place rapidly around the point of fracture. In the poison hairs of certain other forms, a tiny opening in the point of the hair is distinctly visible,

but it has been impossible so far to detect any such pore in the poison hairs of the brown-tail caterpillar even with an oil emersion lens.

If the substance is merely smeared on the outside, however, what is its source and how does it reach the hair? If, as some writers suggest, it is secreted in the two red tubercles on the caudal end of the body, then the long hairs as well as the short ones would be covered with it. This has not proved to be the case. Furthermore, Dr. Tyzzer found that if a hair be dried and then placed in some such stain as Loeffler's alkaline methylene-blue solution, the dye first penetrated the point of the hair and then gradually diffused throughout its entire length. These observations strongly indicate that there is a pore in the point of the hair, but there is one thing that Dr. Tyzzer seems to

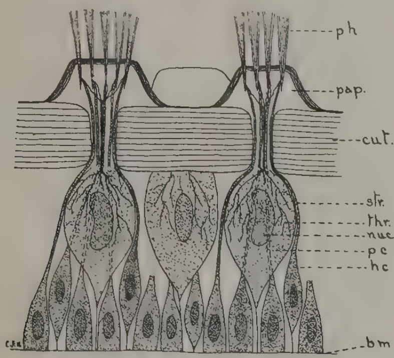

Fig. 4.—Diagram of arrangement of hairs and cells; *ph*, poison hair; *pap*, papilla; *cut*, cuticle; *str*, prolongation of hair formative cell; *thr*, threads of poison; *pc*, poison-secreting cell; *nuc*, nucleus of poison secreting cell; *hc*, hair formative cell; *bm*, basement membrane.

have overlooked. As he says, the nettling hairs occur in groups inserted point first in protuberant rounded sockets or papillae on the subdorsal and lateral tubercles. These papillae are set very close together, although not actually in contact with each other.

Now the hairs of insects are formed simply by the outpushings of certain hypodermal cells, which, projecting above the general level, secrete their cuticle in the form of hair-like prolongations of chitin. The projecting hairs would therefore be hollow and their contents connected directly with the contents of the underlying cell. Then, since the hairs under consideration are inserted point first, this connection must be through the point, and this would leave a pore, or opening, through which the poison may diffuse into the blood when the hair is detached.

The hypodermis of the subdorsal and lateral tubercles is very different in appearance from that of the other regions of the body, being much thicker. This increase in thickness is due to the great length of the cells which lie directly beneath the poison hairs. They are all much elongated, three or four times the length of the ordinary hypodermal cells, and are closely crowded together. The connection between the cells and the poison hairs is effected through pore canals in the cuticle the same as with the ordinary hairs, the only difference being that instead of there being a pore canal for each hair there is one for each papilla on the tubercle, all the hairs on a papilla being reached through the same pore canal (Figs. 3 and 4).

The cells are divided into two groups, one composed of large cells 3.3 microns in diameter, the other composed of smaller ones 1.95 microns to 2.02 microns in diameter. The cells of the first group lie directly under the cuticle (Fig. 3, *pc*) and have crowded out the smaller cells toward the basement membrane, which gives a two-rowed appearance to the hypodermis. These large cells, one of which lies directly under each of the hair-bearing papillae, are composed of granular cytoplasm, corresponding in appearance with that of the ordinary hypodermal cells, with large nuclei which, however, are smaller in proportion to the size of the cell than those of the other group (Fig. 4, *nuc*). In the cytoplasm there are fine threads of a darkly staining substance which converge toward the apex of the cell and unite into a coarser thread which passes through the pore canal in the cuticle and enters the papilla. There it divides again, one thread going to each of the hairs on the papilla (Fig. 4, *ph*).

At first sight these cells bear a slight resemblance to nerve cells with nerve fibers running out from them; but they are rather the poison-secreting cells and the threads, coagulated secretion connected with the individual hairs. This would seem to be the case for three reasons: In the first place, there are no other cells remotely resembling these in any part of the body; this fact in itself being enough to preclude the possibility of their being nerve cells. In the second place, suppose that they were really nerve cells and the hairs instead of being poisonous were merely sensory. What would be the object of having sense organs so loosely attached to the body of the insect that the slightest touch suffices to dislodge them? And what could be their use? Obviously, they could not be tactile, because they are so very short that practically nothing could get to them through the long hairs with which the body is thickly covered. It would take something more stable to serve the purposes of hearing and as for the chemical senses, taste and smell, they are so absolutely different from any other organs of that nature that such a supposition would be unlikely on the face

of it. If sensory, they would seem to be of some sense with which we are unfamiliar and one peculiar to this particular species of caterpillar, especially fitting it for its mode of life. Since its habits are not markedly different from those of a great many of our social caterpillars, the writer is at a loss to account for the necessity of such a highly specialized sense.

Then, since they are evidently not nerve cells, and since they are actively secreting, it would seem legitimate to assume that they are poison cells. The hairs themselves are formed by the smaller cells, as will be shown later, the papillae are merely cuticular appendages and there is nothing else present for which active gland cells could possibly be used.

The cells composing the second group are of a very different appearance from those just described. They are much smaller; measuring from 1.95 microns to 2.02 microns in diameter. They are fusiform in shape, irregularly arranged, and appear as though crowded out of their regular position by those around them. There is comparatively little cytoplasm and it does not contain the threads of poisonous substance (Figs. 3 and 4, *hc*). These cells correspond in number with the hairs and each cell is connected by means of a strand of cytoplasm with a hair. The strands of cytoplasm are in fact nothing more nor less than portions of the cells which extend up around and between the poison cells (Fig. 4, *str*), through the pore canal and papilla directly to the hairs. In other words, the smaller cells are the hair formative cells for this particular kind of a hair.

The basement membrane extends along beneath the second group of cells and is very easily detected, much more so in fact than in the other parts of the body wall; and all the cells, whether poison-secreting or hair formative, are connected with it either lying directly on it or connected by means of fine threads of the cell substance.

Beille (1896) described something very similar to this as obtaining in one of the processionary caterpillars, *Cnethocampa pityocampa* Borowski. In that species the surfaces of the tubercles bearing the urticating hairs are divided into four areas by two bands which cross the tubercle at right angles to each other and which are free from hairs. The four sectors thus made are covered with chitinous papillae which bear the poison hairs and which are connected with the subjacent parts by pore canals in the cuticle in the same way as those of the brown-tail. "The glandular part exists only under the sectors covered with hairs. These glands are separated from each other by connective-tissue strands and a membrane of the same nature separates them from the subjacent organs. These glands are unicellular and are in the form of very elongate pears. . . . In the narrower parts one sees a canal

which is continuous with each of those which cross the chitinous area. These glands are therefore analogous in their structure to those which correspond to the large hairs, and ought to be considered as hypodermal glands."

Unfortunately, there are no illustrations in his paper, and it is somewhat difficult to interpret his descriptions. He says nothing to prove the glandular nature of these cells, and the probability is that some of those that he describes are the hair-formative cells. Judging from the brown-tail, his connective tissue strands are the prolonged distal portions of the hair formative cells. However, that a condition exists similar to that found in the brown-tail seems probable and it is quite probable that further work done on the larvae of the processionary caterpillars will bring out still further evidences of the similarity of their structures.

Probably the nearest approach to the structures found in the brown-tail are those recently described by Eltringham (1914) as occurring in the closely related species *Porthesia* (*Euproctis*) *similis* Fuess. He says that these hairs are connected with *two* rows of hypodermal cells similar to the one row in Figure 3, which cells, he thinks, doubtless secrete the hairs. If two rows of hypodermal cells do exist in this form it is an aberrant condition, and from Eltringham's description and figures it seems probable that what he took for a second row of cells was either an invagination of the body wall, a portion of the hypodermis from some other part of the body which had become displaced in the process of sectioning, or else some other tissue entirely.

There are also figured some very peculiar looking structures which he calls the "plume-like structures." These are said to occur among the urticating hairs and to "arise from a chitinous socket, differing little, if at all, from the sockets of the larger branched hairs, and having at its base several cells apparently of a glandular nature." These "plume-like structures" correspond in position to some of the large branched hairs of the brown-tail and it is possible that what Eltringham took for a single structure is really a group of branched hairs, each hair being connected with one of the cells at the base of the structures.

More work will have to be done on all the poisonous forms before generalizations can be made, but, taking all things into consideration, it is clear that the short barbed hairs occurring on the subdorsal and lateral tubercles of *Euproctis chrysorrhoea* contain a definite poisonous substance and do not act merely as mechanical irritants; and it is probable that a similar condition of affairs exists in a number of different species.

SUMMARY

1. Tyzzer's statement that a definite poisonous principle is contained in the short barbed hairs of the larva of the Brown-tail Moth is confirmed.

2. This substance is secreted by certain specialized hypodermal cells and is liberated in the blood through the sharp basal point of the hairs when they come in contact with the human skin.

3. The poison glands are larger and fewer in number than the cells which form the hairs, there being one poison cell for each papilla on the tubercle instead of one for each hair.

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AN APPEAL TO AMERICAN HELMINTHOLOGISTS

AL. MRÁZEK
Professor of Zoology, Bohemian University, Prague

Some years ago the muskrat was introduced into Bohemia. This animal has not only taken possession of his new home, but soon overspread the whole country and is now continuing his conquering course beyond the boundaries of Bohemia in the neighboring lands of Bavaria, Saxony, etc.

This fact is certainly in zoogeographical respects a very interesting one. It offers, so to speak, an academic instance for demonstrating some general biological laws concerned in the geographical distribution and spreading of animals, an instance that especially for American zoologists would be of some interest as relating to a well known representative of the North American mammalian fauna.

But it is not my intention to dwell here on this point. Nor yet on the economic side of the introduction of the muskrat into Bohemia which has proved to be most disastrous to pisciculture in our country by its destructive action (burrowing in the pond dams, etc.), although this side might be also of some interest to the American zoologists interested in the economic aspect of the science. The muskrat as a fur-bearing animal is of economic importance, and the experiences we have had in Bohemia on the possible, incredible rate of increase in number of individuals, would perhaps give some hints for protective measures in North America.

I will only call attention to the parasitological side of the muskrat problem. It is obvious that a detailed study of the parasitological fauna of the muskrat in his new environmental conditions in Bohemia, respectively Europe, might throw some light on several general problems of parasitology.

I have myself already commenced this study, but I soon learned with regret and to my discomfiture, that the indispensable comparative basis for such studies, a knowledge of the parasites of the muskrat in his original American home, is lacking. I find this confirmed in a paper recently published by an American colleague, Professor Barker (Lincoln, Neb.), who also states that very little is known on the parasites of the muskrat. For this reason I beg to draw the attention of American helminthologists to this point and recommend to them the study of the parasites of one of the most typical North American mammals.

I am sincerely glad that I have the opportunity to publish this appeal in the columns of a new American journal devoted to the study of parasitology. I greet and welcome this journal and I am sure that it will contribute much to the general progress of parasitology.

KILLING SMALL ARTHROPODS WITH THE LEGS EXTENDED

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Entomologist, Montana Agricultural College, Bozeman.

Any one who has worked with alcoholic ticks recognizes the disadvantage of the curled position of the legs which is usually assumed in such specimens. In connection with experiments in methods of preserving female ticks in various stages of engorgement, it was accidentally learned that flat or unfed females, and all males, are left with the legs extended if killed by dropping into boiling water. Specimens so treated also become slightly distended, which is often an advantage.

The ticks are dropped, one at a time, from a height of 6 or 8 inches into a small dish of water over a flame. A pair of fine curve-pointed forceps is used for picking up and dropping the ticks, and a minute strainer on a handle is convenient for removing them from the water. Specimens which are removed as quickly as possible have the legs properly extended, but we have not observed any injury to others allowed to remain immersed longer.

Partly engorged females are improved as specimens if treated in this way, but larger females may be overdistended or may be injured by a cracking and slipping of the integument. Nymphs killed in this manner make better specimens, and it is probable that larvae would also be improved, though we have not tried the method on them.

Assistant Entomologist J. R. Parker has tried this method in killing aphids before clearing in turpentine-carbolic acid mixture, and finds that the legs are generally extended in symmetrical positions as with ticks. In the case of aphids this is apparently due to the legs being fixed in the position they have when they touch the water rather than to an extending of the legs after immersion. With ticks and aphids at least, this method appears to be of great value, and it is probable that with many other arthropods its adoption would be beneficial.

In this connection it may be of interest to state that living, unfed ticks may be induced to extend the legs by squeezing them lightly between two pieces of glass. In this position they may be photographed or examined under a binocular microscope without injuring them. For this purpose we have used a thin microscopic slide on one side and a seven-eighths by 2-inch cover-glass on the other, the two being held together by rubber bands. The cover-glass curves and touches the slide at both ends, and the amount of pressure on the tick is governed by varying the distance between the two rubber bands.

SOCIETY PROCEEDINGS

THE HELMINTHOLOGICAL SOCIETY OF WASHINGTON

The twenty-first regular meeting of the society was held at the residence of Mr. Crawley, Sept. 22, 1914, Mr. Crawley acting as host and Mr. Foster as chairman. Dr. R. T. Shields of Nankin, China, was a guest of the Society.

Mr. Crawley gave a demonstration of a Leitz microscope, designating some of the recent improvements.

Dr. Shields gave a talk on the parasites of man and the domestic animals around Nankin.

Mr. Hall reported a second case of *Fasciola magna* in the sheep. The fluke was found in a liver sent in from Ovando, Mont., where a number of sheep had died. These sheep showed black markings of the omentum and abscesses of the liver, lungs or spleen. A spleen that was sent in was very much enlarged and full of what appeared to be embolic bacterial abscesses. *Fasciola magna* in cattle apparently exerts little influence on the health of infested cattle. It is however, rather interesting to note that in this case and in the first case of *Fasciola magna,* reported by Hall in 1912, attention was called to the presence of the parasite by the fact that numbers of sheep were dying in each case. It seems very likely that *Fasciola magna* exerts considerable effect on the general health of infected sheep, even causing death in a rather high percentage of cases, but this is a matter that needs further investigation. In the previous cases the sheep were noted as showing emaciation, edema and peritonitis.

MAURICE C. HALL, *Secretary.*

NOTES

For the purpose of extending the investigations and experimental work relative to the parasites of live stock, the Zoological Division of the Bureau of Animal Industry has obtained a farm near Vienna, Va., where a study will be made of various problems in the control and eradication of the internal parasites of sheep.

The University of Illinois has begun the publication of a quarterly series entitled Illinois Biological Monographs. The first, a double number, is devoted to A Revision of the Cestode Family Proteocephalidae by George R. La Rue. Extended notice will be given this paper in a later number of the JOURNAL.